

**Open-Ended Play With Magnetic Unit Blocks:  
The Educational and Collaborative Impact of  
Modular Mighty Magz on 4-6 Year-Old Children**

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### **Abstract**

The goal of this study was to investigate whether young children's collaborative play and learning about magnetism could be enhanced by open-ended play with an innovative type of magnetic unit blocks that teachers could use in conjunction with an explicit lesson about magnetism. This research was completed as part of a dual thesis: the BXA Capstone Project and the H&SS Honors Thesis. The BXA Capstone Project was dedicated to the design and construction of the toy: Modular Mighty Magz. The H&SS Honors Thesis was dedicated to the experimental evaluation of the educational and collaborative impact of Modular Mighty Magz. The four-year-olds and kindergarten children at the Carnegie Mellon Children's School participated in four different assessments. Children were given a three part pre- and post-test interview that asked questions about magnets and magnetic fields, magnetic poles, and magnetic versus non-magnetic objects. Between the pre- and post-test interviews, the children's teachers did a group lesson about magnetism during circle time and then gave the children time in groups of four to play with either Modular Mighty Magz or a common magnet toy, Mega Magz, in a separate room for 15 minutes. The play time was used to determine the collaborative impact of Modular Mighty Magz versus Mega Magz. A 2 (age [four-year-olds/kindergarten]) x 2 (toy [Modular Mighty Magz/Mega Magz]) mixed design ANOVA was conducted for all four of the dependent measures. Overall the results showed that every child improved, with kindergartners performing better than the four-year-olds, between the pre- and post-test interviews on the magnet and magnetic field questions and magnetic pole questions. This demonstrated the creation of an effective teacher lesson. There was a three-way interaction between age, toy used, and the magnetic versus non-magnetic object questions. It was determined that the four-year-olds did not improve on this test or have any benefit in which toy they used. However, the children

who were given Modular Mighty Magz and were in kindergarten had a significant improvement in responses to these questions whereas those who got the Mega Magz did not improve on their scores. Children in both age groups spent significantly more time collaborating with the Modular Mighty Magz than with the Mega Magz. Thus, the teacher lesson effectively taught the children concepts of magnetism. Even with only a fifteen minute play session, the materials I designed, Modular Mighty Magz, were more effective than an existing toy in improving concepts for the kindergartners regarding magnetic versus non-magnetic objects and in promoting collaboration for all ages.

**Open-Ended Play With Magnetic Unit Blocks:  
The Educational and Collaborative Impact of  
Modular Mighty Magz on 4-6 Year-Old Children**

The purpose of this study was to determine how to support young children's collaborative play and learning about magnetism through designing a toy that teachers could use in conjunction with an explicit lesson about magnetism. Originally I planned to create a toy for the children at the Carnegie Mellon Children's School for my BXA Capstone Project. However, my goal was to go beyond designing a toy that is engaging and fun, to create a toy that is also educational and effective in teaching important school concepts. Therefore this study was completed for the H&SS Honors Thesis and in collaboration with the BXA Capstone Project to create a dual thesis. The report of my design process for Modular Mighty Magz, which also supports improving fine and gross motor skills, one of the developmental goals of the Children's School (Carnegie Mellon University Children's School, 2004), is separate from this study and referenced in my BXA Capstone Project.

The rationale for promoting collaboration is that it is one of the four C's in *Learning and Innovation Skills*, which is one of the four main components in the framework of goals for twenty-first century skills (Partnership For 21<sup>st</sup> Century Skills, 2011). The goal of this framework is to build an education system to prepare children for the changing world. It works more to give them the necessary skills to adapt to the changing world than memorizing facts and knowledge, because the world is changing at such a fast pace that we cannot predict what is necessary for children to know in the future. All we know now is that the most important thing is to be able to be adaptive and solve new problems as they arise. The Pennsylvania Department of Education also lists collaboration with social identity in section 25.4.1 under the broader heading

of *Pro-Social Relationships With Peers*. It states that during free choice time children should be able to initiate play with two to three peers, participate in cooperative learning activities to complete desired tasks, or play cooperatively with three or four children for a sustained period of time (Pennsylvania Department of Education, 2009).

Concepts of magnetism fall under the topic of STEM (Science, Technology, Engineering, and Math) improvement in education. In section 3.2b.4, the Pennsylvania Department of Education talks about how magnets fit into the broader heading of physical sciences for their kindergarten standards. They expect kindergarten children to be able to talk about concepts of magnetic force and use them. Kindergarten children are expected to attach objects to magnets, explain what happens near magnets, and distinguish items that are magnetic and non-magnetic (Pennsylvania Department of Education, 2009). However, after attending a joint professional development program between the Harvard Graduate School of Education and Harvard Graduate School of Design last summer, I knew more could be taught to the children. Just as we talked in the institute that the future of education in physical school designs should be for the future and not the present, why not try to teach more advanced concepts to the children? If we fix the present solutions, they will be obsolete by the time it is implemented. Therefore we need to design for the future by predicting the problems children will face and how they will overcome them. While the Pennsylvania Department of Education Kindergarten Standards served as a baseline of knowledge for the kindergarten children and a benchmark for the four-year-olds at the Carnegie Mellon Children's School, my goal was to teach more advanced concepts to the kindergarten and four-year-olds than they are currently required to know. In this way, my toy design could improve the current STEM curriculums, as well as have a broader range of potential users.

The more advanced concepts to which the children were introduced included magnetic fields, magnetic poles, advanced vocabulary such as attracting and repelling, and metallic but non-magnetic objects such as gold, copper, and aluminum. None of these concepts are specifically mentioned in the Pennsylvania Department of Education Kindergarten Standards. In fact the National Research Council on K-12 science education does not even break down what children should know beyond second, fifth, eighth, or twelfth grade. Therefore if the children achieved any of the concepts listed under second grade, I was far exceeding the Pennsylvania Department of Education Kindergarten Standards. Magnets falls under core idea PS2: *Motion and Stability: Forces and Interactions* by the National Research Council. Under section PS2.B second graders are expected to know that objects can change motion or shape when they touch or collide. It is not until by the end of fifth grade that children should know that the orientation of magnets depends on what forces act on them and that magnets need not be in contact to push or pull a magnetic object. By the end of eighth grade, the terms attract and repel are mentioned, and magnetic field concepts are listed for the end of grade twelve (National Research Council, 2011). Through reading the language of the National Research Council, one could easily make the case that I aim to teach kindergarten children concepts learned in second grade, middle school, and even high school. For my study, the teacher lesson focused on these advanced concepts in terms children of this level could cognitively understand, so that the toy I designed might reinforce children's learning about magnetism.

## **Method**

### **Design**

In order to test the impact of this lesson and related magnet play on children's concepts of magnetism and collaborative play, this study involved a 2 x 2 between subjects design. The



independent variables were age (four-year-olds versus kindergarten) and toy (Modular Mighty Magz versus Mega Magz). Every child was given a pre- and post-test interview that included three dependent measures (magnet and magnetic field questions, magnetic pole questions, and magnetic versus non-magnetic object questions). Then each classroom had a teacher lesson on magnetism followed by being randomly assigned to play with one of the two toys, in groups of four for fifteen minutes.

### **Participants**

This study tested forty-two four-year-olds and kindergarten children ( $M = 5$  years, 1 month) at the Carnegie Mellon Children's School. There were seventeen kindergarten children ( $M = 5$  years, 7 months) and twenty-five four-year-olds ( $M = 4$  years, 10 months). Two kindergarten children and one four-year-old were excluded for not being available for the post-test. One kindergarten child and one four-year-old were excluded for not being available for the teacher lesson and play day. See Table 1 for a breakdown of ages, gender, and assignment to condition.

### **Materials**

**Pre- and post-test interview.** For the pre- and post-test interview, a series of questions about magnets and magnetic fields, magnetic poles, and magnetic versus non-magnetic objects was generated (see Appendix A). In part one, the children were asked questions about what they know about magnets, what they can do with magnets, what a north and south pole on a magnet is, what the word attract and repel means, what a magnetic field is, and where the magnetic field is located. During the "show me where the magnetic field is" question, two circular magnets were required. In part two, the children were asked to judge whether certain combinations of magnetic poles, such as a north and a north pole, would attract, repel, or they did not know.

Finally, in part three the children were shown a series of flash cards and asked to decide if a magnet would stick to the object in the picture. During the flash card part of the interview children were given one of three sets of cards cut out from the template provided in Appendix B for the pre-test and a different set for the post-test to counterbalance the sets. The objects for all three sets included six magnetic objects (metal desk items, metal tools, metal hardware, metal silverware, metal sewing items, and magnets) and six non-magnetic objects (plastic, wood, aluminum, copper, gold, and rubber). The children were given one of two circular magnets (see Figure 1) and asked if it would stick to the object in real life. North and south was not marked on these magnets.

**Teacher lesson.** The teacher lesson followed a written script (see Appendix C) and used a giant paper pad (see Figure 2) to record children's responses to questions and draw the magnetic concepts. The teacher used a bar magnet with north and south marked to explain the poles and eventually every child used two circular magnets that had north and south marked (see Figure 3) to explore the magnet concepts. The teacher also used twelve objects similar to the flash cards (see Figure 4) to talk about what objects were magnetic and non-magnetic. The twelve objects used in the demonstration were six magnetic objects (staples, vice grips, bolt, can opener, metal shoehorn, plastic magnetic cube) and six non-magnetic objects (plastic measuring spoon, wooden dowel, aluminum mesh, copper nail, gold earring, rubber ring).

**Modular Mighty Magz.** This study also used commercial as well as originally made toys to compare how well they reinforce children's concepts of magnets during the play part of the experiment. *Modular Mighty Magz: The Wooden Unit Block System* was designed for my BXA Capstone Project thesis. They are handmade wooden unit blocks that have been magnetized to allow children to play with blocks in a whole new way and dimension (see Figure 5). Children

were given seventy-six blocks that have been constructed of three kinds of wood: ash, cherry, and walnut. There were twenty 2" x 2" x 1" squares, eight 2" x 4" x 1" rectangles, four 2" x 6" x 1" rectangles, four 2" x 8" x 1" rectangles, sixteen 2" x 2" x 1" triangles, sixteen 2" x 4" x 1" triangles, and eight special direction 2" x 2" x 1" squares (magnets were located under the four short sides of the blocks versus under the two larger surfaces of the other blocks). See Figure 6 for the individual kinds of blocks. The ash surfaces do not stick to any other surfaces as there are no magnets under it. The cherry surfaces are the north pole and the walnut surfaces are the south pole of the blocks. Children learn about concepts of poles by noticing that opposite woods attract (cherry and walnut) and similar poles repel (cherry and cherry or walnut and walnut) just like magnetic poles. To reinforce these concepts, the magnets inside are extremely powerful and much stronger than any toy on the market. The strength of the magnets also lets them build shapes and structures not possible with standard wood blocks or weak magnet toys. To accomplish this, children could make cantilevered structures not possible with wooden blocks or stack blocks out further without falling over, by placing the blocks one on top another in a horizontal direction from a vertical plane, which is not possible with traditional weak magnet toys. The play space was designed so children could stick the magnetic blocks on a steel plate or magnetized points in the bottom wood board. The board was magnetized so that the north pole was pointing toward the ceiling of the room. The rods that hold the boards up were made of aluminum and not magnetic. The children were presented with the blocks divided evenly in two plastic bins based on the number and type of blocks in two chairs next to a table with the play space created to play on.

**Mega Magz.** The Children's School owned a bin of Mega Magz that was used for this study as the commercial toy for comparison. It contained remnants of four typical 130 piece

Mega Magz sets (see Figure 7). Mega Magz are a series of steel balls and plastic rods with magnets in them. This study used 144 steel balls, 24 four-point rods, and 307 bars (see Figure 8). The pieces allow for an unlimited possibility of structures based on using geometrical designs. Table 2 lists a comparison of the two different toys' affordances for learning magnetic concepts.

### **Procedure**

This study followed IRB (Institutional Review Board) procedures for working with human subjects and the Children's School's policies for testing children.

**Pre-test interview.** Children were brought individually to a testing room from the classroom during activity time to conduct the three part pre-test interview (see Appendix A). Children were all asked the same questions, except each was randomly assigned to one of the three flash card conditions (see Appendix B) during the pre-test interview and a different set for the post-test interview. After the child had finished the experiment, he or she was given a sticker and parent description. See Appendix E for the parent description of the research.

**Teacher lesson.** Each teacher was given a script ahead of time to prepare for the lesson (see Appendix C), as well as a large pad of paper to record the children's responses to the questions and all materials necessary to teach the lesson. All objects and scripts were the same for each of the four teachers involved in the study. The concepts in the lesson covered everything that was addressed in the pre- and post-test interview. After the teacher explained the concepts of magnets, the children were each given a pair of magnets marked with north and south to practice and see the concepts taught, such as north and south poles attracting and repelling. Lastly, the magnets were collected and the teacher gave a demonstration with six magnetic objects (staples, vice grips, bolt, can opener, metal shoehorn, plastic magnetic cube) and six non-magnetic objects

(plastic measuring spoon, wooden dowel, aluminum mesh, copper nail, gold earring, rubber ring) similar to the objects on the flash cards used in the pre- and post-tests.

**Play session.** After the teacher lesson and the rest of circle time, children were brought in groups of four to the Green Room Annex Classroom at the Children's School. Each group of four was randomly assigned to use one of the two toys, Modular Mighty Magz or Mega Magz. The children were videotaped while they played so that the tape could be used to code the amount of time each child collaborated during the free play, and the teacher who taught the lesson was present to supervise the children. The experimenter and teacher remained silent except to encourage the children to play however they wanted. The children were allowed to play for fifteen minutes and the experimenter used prompts at set time intervals to encourage the next level of play with the toy (see Appendix D). Other interventions included making sure the children returned to play with the toy if distracted by other objects in the classroom. The fifteen minute time frame was used because of the logistical time limits allowed for testing the children at the Children's School. Activity time lasted only an hour and the play session was required to be done directly after the teacher lesson. Since at least two groups were tested per teacher, the time it took to retrieve children, and the time to set-up and dismantle the two toys, only two groups could be tested per day in the hour time frame. Theoretically, fifteen minutes was also chosen based on the attention span of the children. If the play time was longer, the children may have become fatigued or if the play time was shorter the children would not have had enough time to play and learn from the toy. Due to the short duration of time available to test, in future studies it might be better to do a fifteen minute intervention for multiple days in a row to really give the children time to explore the toys and learn the concepts.

**Post-test interview.** Children were brought individually to a testing room from the classroom during activity time to conduct the three part post-test interview that was the same as the pre-test interview (see Appendix A). The only difference was each child having a different set of flash cards for the magnetic versus non-magnetic distinction questions. After the child had finished the experiment, he or she was given a sticker and parent description.

### **Results**

The research question was to determine how to support young children's collaborative play and learning about magnetism through designing a toy that teachers could use in conjunction with an explicit lesson about magnetism. Assessment of peripheral variables of gender (two levels and between-subjects [male or female]) and flash card set number (three levels and between-subjects [set 1, set 2, and set 3]), revealed no statistical differences ( $p$ -values greater than 0.05), so neither gender nor set number was included in the remaining analysis. A 2 (age [four-year-olds/kindergarten]) x 2 (toy [Modular Mighty Magz/Mega Magz]) mixed design ANOVA was conducted for all three of the dependent measures (Part 1: magnet and magnetic field questions, Part 2: magnetic pole questions, and Part 3: magnetic versus non-magnetic object questions). Children could score a maximum of nine points and minimum of zero points on the magnet and magnetic field questions, a maximum of three points and minimum of negative three points on the north and south pole questions, and a maximum of twelve points and minimum of zero points on the magnetic versus non-magnetic questions. (See Appendix A for scoring.) Also an independent samples t-test was conducted to compare the overall time of collaboration for groups playing with Modular Mighty Magz versus Mega Magz. To gain a deeper understanding of the collaboration time, a 2 (toy [Modular Mighty Magz/Mega Magz]) x 2 (age [four-year-

olds/kindergarten]) independent groups ANOVA was conducted for individual children's collaboration time.

**Part 1.** Table 3 shows that both four-year-olds and kindergartners improved by about two points out of nine on Part 1 of the pre-post test interview. The statistical results for the mixed design ANOVA showed that on the interview questions for magnets and magnetic fields at a significance level of  $\alpha = 0.05$ , there was a significant difference between pre- and post-test interview scores,  $F(1,33) = 49.11$  and  $p$ -value less than 0.05. There was no significant interactions since the  $p$ -values were greater than 0.05. Age was also significant for this set of interview questions,  $F(1,33) = 13.55$  and  $p$ -value less than 0.05. Through looking at Figure 9, one can see that the kindergarten children performed better than the four-year-old children. The toy used turned out to not be significant since the  $p$ -value was greater than 0.05. This gives us statistical evidence to suggest that the teacher lesson helped both groups improve scores overall on magnets and magnetic fields with the kindergarten children performing better than the four-year-old children. The kindergartners started with more knowledge and learned equally, but they were not close to ceiling. Based on qualitative review of the answers, it appears that they understood what is a magnet, what we can do with magnets, what the north and south pole on a magnet is, and what the word attract and repel meant, but still need intervention on what is a magnetic field and where is the magnetic field.

**Part 2.** Table 4 shows that four-year-olds improved by almost one point out of three and kindergartners improved by almost two points on a scale of -3 to +3 on Part 2 of the pre-post test interview. The statistical results for the mixed design ANOVA showed that on the interview questions for north and south poles that everyone improved overall,  $F(1,33) = 16.01$  and  $p$ -value less than 0.05. At a marginal significance level of  $\alpha = 0.10$ , there was an interaction between age

and interview used,  $F(1,33) = 3.23$  and  $p = 0.08$ . Age and toy were not significant since the  $p$ -values were greater than 0.05. Paired samples t-tests were conducted to determine the nature of the interaction. The statistical results showed that four-year-old children improved their scores between pre- and post-test interview,  $t(22) = 2.29$  and  $p = 0.03$ , as well as kindergarten children,  $t(13) = 3.09$  and  $p = 0.01$ . There was no statistical difference between scores of four-year-old children and kindergarten children on the pre-test interview since the  $p$ -value was greater than 0.05. This result means that everyone was on an even playing field of knowledge before the teacher and toy intervention. There was a statistical difference on the post-test interview,  $t(35) = 2.35$  and  $p = 0.02$ . Looking at the means and standard deviations, one can see that the kindergarten children performed much better on scores of the post-test interview than the four-year-old children (four-year-old children:  $M = 0.52$  and  $SD = 0.85$  on pre-test and  $M = 1.22$  and  $SD = 1.41$  on post-test / kindergarten children:  $M = 0.43$  and  $SD = 2.24$  on pre-test and  $M = 2.29$  and  $SD = 1.20$  on post-test). This gives us statistical evidence to suggest that the teacher intervention helped improve scores on knowledge of north and south poles, with the kindergarten performing much better. The toy was not statistically significant in helping learn this knowledge for either age. Based on qualitative review of the answers, it appears that the children understood best that a south and a south pole repel, than north and north pole repel, but still needed intervention on the concept of north and south poles attracting.

**Part 3.** Table 5 shows that four-year-olds improved by about half a point out of twelve whereas kindergartners improved by almost one point out of twelve on Part 3 of the pre-post test interview. The statistical results for the mixed design ANOVA showed that on the interview questions for magnetic and non-magnetic objects that there was a marginally significant three way interaction between interview test, age, and toy used,  $F(1,33) = 4.06$  and  $p = 0.052$ . Age was



also marginally significant as well,  $F(1,33) = 3.52$  and  $p = 0.07$ . Test interview and toy used was not significant since  $p$ -values were greater than 0.05. When a follow-up 2 (test interview [magnetic versus non-magnetic objects]) x 2 (toy [Modular Mighty Magz and Mega Magz]) mixed design ANOVA was performed for the four-year-olds there was no difference in pre- and post-test interview scores and no interaction with toy used since the  $p$ -values were greater than 0.05. When a follow-up 2 (test interview [magnetic versus non-magnetic objects]) x 2 (toy [Modular Mighty Magz and Mega Magz]) mixed design ANOVA was performed for the kindergarten children there was a significant interaction between test interview scores and toy used,  $F(1,12) = 4.92$  and  $p$ -value is less than 0.05. There was no main effect of toy used or test interview since the  $p$ -value was greater than 0.05. Paired samples  $t$ -tests were used to determine the nature of the interaction. When looking at the score differences between kindergarten children playing with Mega Magz there was no difference in scores since the  $p$ -value was greater than 0.05 (pre-test  $M = 10.17$  and  $SD = 2.14$ , post-test  $M = 9.50$  and  $SD = 0.55$ ). However, kindergarten children who were given Modular Mighty Magz did significantly better between pre- and post-test interview scores,  $t(7) = 2.97$  and  $p = 0.02$  (pre-test  $M = 9.00$  and  $SD = 1.31$ , post-test  $M = 10.75$  and  $SD = 0.89$ ). It was also determined that between the two toys there was no difference on the pre-test since the  $p$ -value was greater than 0.05 ( $M = 10.17$  and  $SD = 2.14$  for Mega Magz and  $M = 9.00$  and  $SD = 1.31$  for Modular Mighty Magz) but there was a difference on post-test score,  $t(12) = 3.03$  and  $p = 0.01$ . Looking at the means and standard deviations, one can see that Modular Mighty Magz did much better than Mega Magz post-test scores ( $M = 9.50$  and  $SD = 0.55$  for Mega Magz and  $M = 10.75$  and  $SD = 0.89$  for Modular Mighty Magz). It was good that there was no difference on the pre-test since it meant all the children had equal knowledge before the intervention and then the post-test showed that play

with Modular Mighty Magz improves performance. All of this gives us statistical evidence that for the magnetic versus non-magnetic object questions, the teacher lesson and toy had no effect on improved performance for four-year-old children. However, using Modular Mighty Magz improves performance on these kinds of questions with the teacher lesson for kindergarten children (see Figure 10). Based on qualitative review of the answers, with a success rate of 75% overall, and looking at Table 6, it appears that four-year-olds understood the magnetic properties of metal desk items, metal tools, metal silverware, magnets, plastic, wood, and rubber, but still need intervention on metal hardware, metal sewing items, aluminum, copper, and gold. Whereas for the kindergartners, it appears that they understood magnetic properties of metal desk items, metal tools, metal hardware, metal silverware, metal sewing items, magnets, plastic, wood, and rubber, but still needed intervention on aluminum, copper, and gold except the group with Modular Mighty Magz.

**Collaboration.** Table 7 shows that children collaborated about two minutes longer with Modular Mighty Magz than Mega Magz for four-year-olds and about four minutes longer with Modular Mighty Magz than Mega Magz for kindergartners. An independent samples t-test was performed to see the difference in time collaborated for Modular Mighty Magz versus Mega Magz. This test showed that there was a significant difference between time collaborated with the two toys,  $t(8) = 3.34$  and  $p = 0.01$ . Looking at the means and standard deviations, it is evident that children collaborated significantly longer with Modular Mighty Magz than Mega Magz (Modular Mighty Magz  $M = 5.25$  and  $SD = 2.92$  and Mega Magz  $M = 0.75$  and  $SD = 0.74$ ). This gives us statistical evidence to suggest that Modular Mighty Magz is a much more effective in promoting collaboration for four-year-olds and kindergarten children than Mega Magz (see Figure 11).

Lastly, to reinforce the idea of which toy was more collaborative a 2 (age [four-year-olds/kindergarten]) x 2 (toy [Modular Mighty Magz/MegaMagz]) independent groups ANOVA was conducted for time collaborating for each child. These results showed that age does not matter since the  $p$ -value was greater than 0.05. However the toy used was significant  $F(1,33) = 13.40$  and  $p = 0.01$ . Through looking at Figure 12, one can see that Modular Mighty Magz had children significantly collaborating longer than children with Mega Magz. This gives us statistical evidence to suggest that Modular Mighty Magz was a more collaborative toy for both the four-year-olds and kindergarten children than Mega Magz.

### **Discussion**

The most important finding for this study was that kindergarten children who played with Modular Mighty Magz after their lesson on magnetism learned significantly more about magnetic versus non-magnetic objects than those who played with Mega Magz. They also collaborated for more time with Modular Mighty Magz than with Mega Magz. Though the study was small and the play time limited, the results suggest that Modular Mighty Magz is a more educational and collaborative toy than a similar common magnet toy, Mega Magz. If more extensive intervention studies with a broader population yield similar positive results, my toy may have the potential to be used for improving magnetic concepts in schools across the country one day if mass produced and marketed. On the other hand, when one digs deeper into the results, I believe more questions have been generated than answers.

The first question to analyze is why did the kindergarten children do better only on the magnetic versus non-magnetic object questions? By looking at the item details, it becomes clear that the concepts that increased the most were that children became more able to correctly identify that aluminum, copper, and gold were non-magnetic after playing with Modular Mighty

Magz than with Mega Magz. In fact, scores seemed to remain the same or decrease for the kindergarten children with Mega Magz (see Table 6). If one thinks about the Modular Mighty Magz toy, it comes with two aluminum bars for support. Children in that group were given that opportunity to try that material and notice it was non-magnetic during their play even though it was not the focal point of the toy. They were also presented with the large steel plate constantly in their visual field to reinforce the concept that magnets stick to metal on their play space. Another thing I noticed during the play of the children is they were much more attuned to the blocks' magnetism. A few children ran around the room testing what was magnetic and non-magnetic when they became tired of sticking the blocks together. I think further studies with this toy would have to be conducted to see if this effect holds true. There was also a smaller sample size that could have affected scores with the kindergarteners than the four-year-olds.

Further studies should also include glass into the experiment. Several children commented that the magnet stuck because it was a glass object when in fact it was not. This misconception appeared during the magnetic versus non-magnetic questions in the pre- and post-test interviews. After talking to teachers and thinking about it for awhile, we have come to the conclusion that children may be confused by the static cling properties of the plastic objects that can stick to windows. Since the objects "stick," they may think it sticks like a magnet versus using friction instead, which is a complex concept for children this age to understand. Further research could be done to teach children about different kinds of object hold: magnetism versus friction.

Modular Mighty Magz was specifically designed to reinforce the concept of magnetic poles, yet the children did not improve on the magnetic pole questions more with Modular Mighty Magz than Mega Magz. I saw evidence of a few kindergarten children starting to figure

out the poles on the Modular Mighty Magz. A few commented on the wood colors and tried to show their findings to other children. I think that due to the short duration of only fifteen minutes of play the children were not able to discover this subtle design of the toy. If future research were to be done with multiple play sessions over a week, perhaps the Modular Mighty Magz would prompt the children to discover this concept. Also, if the blocks were designed to be marked explicitly with “N” for north and “S” for south, this concept might have improved more as well. However, this was omitted in the design process to create a more attractive and less gaudy toy.

All the improvement in the magnetic poles and magnetic field questions came from the questions that did not relate to magnetic fields. In fact, only about three children got both of those questions correct in the entire study. This challenge may be due to the concept being too advanced for this age, as it appears at the twelfth grade level for the National Research Council. However, this concept could possibly be taught as well to the children with Modular Mighty Magz if more play time was offered. The children who got these questions correct were in the Modular Mighty Magz condition, and I saw them demonstrating to the teacher the motion taught in the lesson by the teacher and explaining the magnetic field idea (see Figure 13).

It was also notable that only the kindergartners showed improvement with the Modular Mighty Magz. Perhaps the play time was too short for the four-year-olds to learn everything. Alternatively, this toy might be more developmentally appropriate for kindergartners but not younger.

Based on the teachers’ lesson however, all the children improved over the course of the study. This evidence demonstrates effectiveness of the magnet intervention curriculum I developed. The teachers in the four-year-old program indicated that they had not previously offered lessons on magnets; whereas the kindergarten teacher had already taught them about

magnets and believed they understood. My data show that my intervention built upon and improved both groups' knowledge.

By looking at the play space of the two toys, it is evident how children learned to collaborate better with Modular Mighty Magz than Mega Magz. The first reason for this difference is that the children were essentially required to share on Modular Mighty Magz due to the design of the play space. At a minimum, this toy could hold two children individually. But by placing the two children next to each other, they had to learn to share the play space or work together to create a larger structure. I had created a problem they needed to solve and they seemed to pick collaborating more over playing individually since it seemed more beneficial for building larger structures. Also children would move to collaborate with the other two children on the opposite side of the board if a child's temperament made him or her want to only play individually on one of the sides (see Figure 14).

The children had the same opportunity to collaborate with Mega Magz because the four children had only one table to work on. In fact, the table made it easier for all four children to see each other and work with one another if they chose this opportunity. However, the small nature of the pieces seemed to promote smaller individual structures or moving to the floor away from everyone else (see Figure 15). Another argument is that Mega Magz may have been created for individual play, but I was trying to adapt it for collaborative play. The only direct verbal interaction between all the children was actually conversations about favorite subjects such as television shows, rockets, or making guns and weapons. Further product testing and research could be done with Modular Mighty Magz to see if children who use it outperform those who use other common magnet toys that may be more collaborative in nature. Mega Magz was chosen because it was the most similar object on the market to Modular Mighty Magz in terms of

allowing diverse structures and similar structures to what could be achieved with Modular Mighty Magz.

In conclusion, I think the evidence shows the potential for Modular Mighty Magz to be used in schools, museums, or homes one day. I was able to teach kindergartners some pretty advanced concepts that are not required until much later in schooling. However due to the population used and short duration of fifteen minutes of play, further research and product testing would need to be done to support and extend these findings. Finding any significant results after just fifteen minutes of play is remarkable, and the collaboration evident with Modular Mighty Magz also makes a case for it to be marketed one day. Teachers are always seeking ways to get children to work together, and this toy is an example of something that could work. The successful lesson about magnets for preschoolers and kindergartners could also be shared with the toy to demonstrate the explicit intervention that prompts learning for the play sessions. The script attached in this paper could easily be used and adapted to help teachers teach about magnetic concepts for young children. Future research with Modular Mighty Magz should investigate the play features necessary for supporting learning, as well as the necessary duration of play. The research could also be deepened by documenting the type of block structures built with the Modular Mighty Magz to determine whether children progress through the same block building strategies as with Modular Mighty Magz unit blocks (Family Building Basics, 2011). Researchers could also test multiple contexts for using Modular Mighty Magz in schools, museums, and homes.

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*Figure 1.* Magnets given during pre- and post-test interview that did not have the north and south poles marked.



Figure 2. Large pad of paper used to write the responses of the children during the lesson.

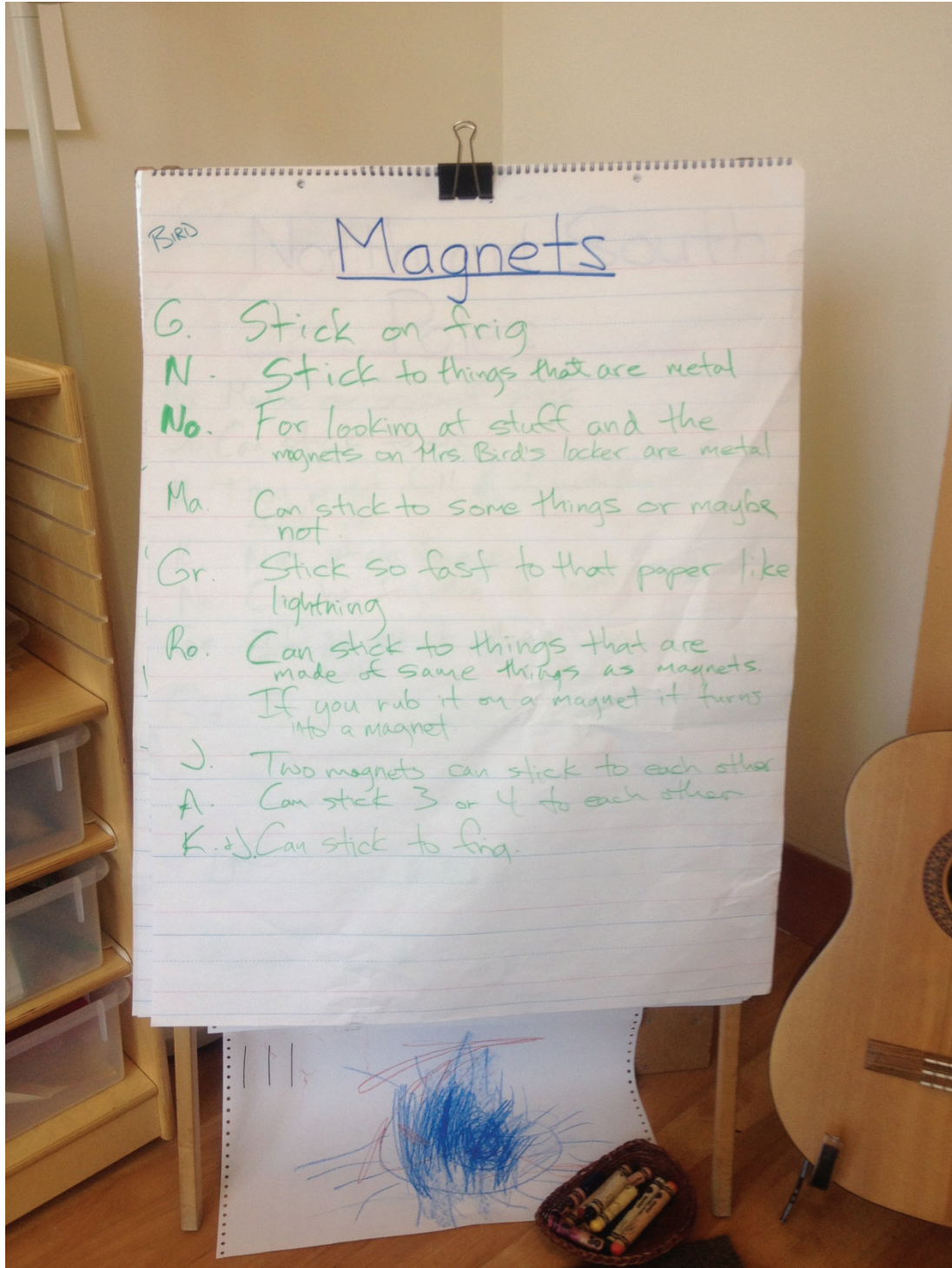


Figure 3. Magnets given to the children that had the north and south poles marked on them.



*Figure 4.* Objects used by the teacher during the lesson: two bar magnets with north and south marked and a set of twelve items similar to the flash cards. The magnetic objects were a shoehorn, bottle opener, vice grips, plastic coated neodymium cube magnet, staples, and a bolt. The non-magnetic objects were a gold earring, copper nail, aluminum mesh, plastic measuring spoon, piece of rubber, and wooden dowel.



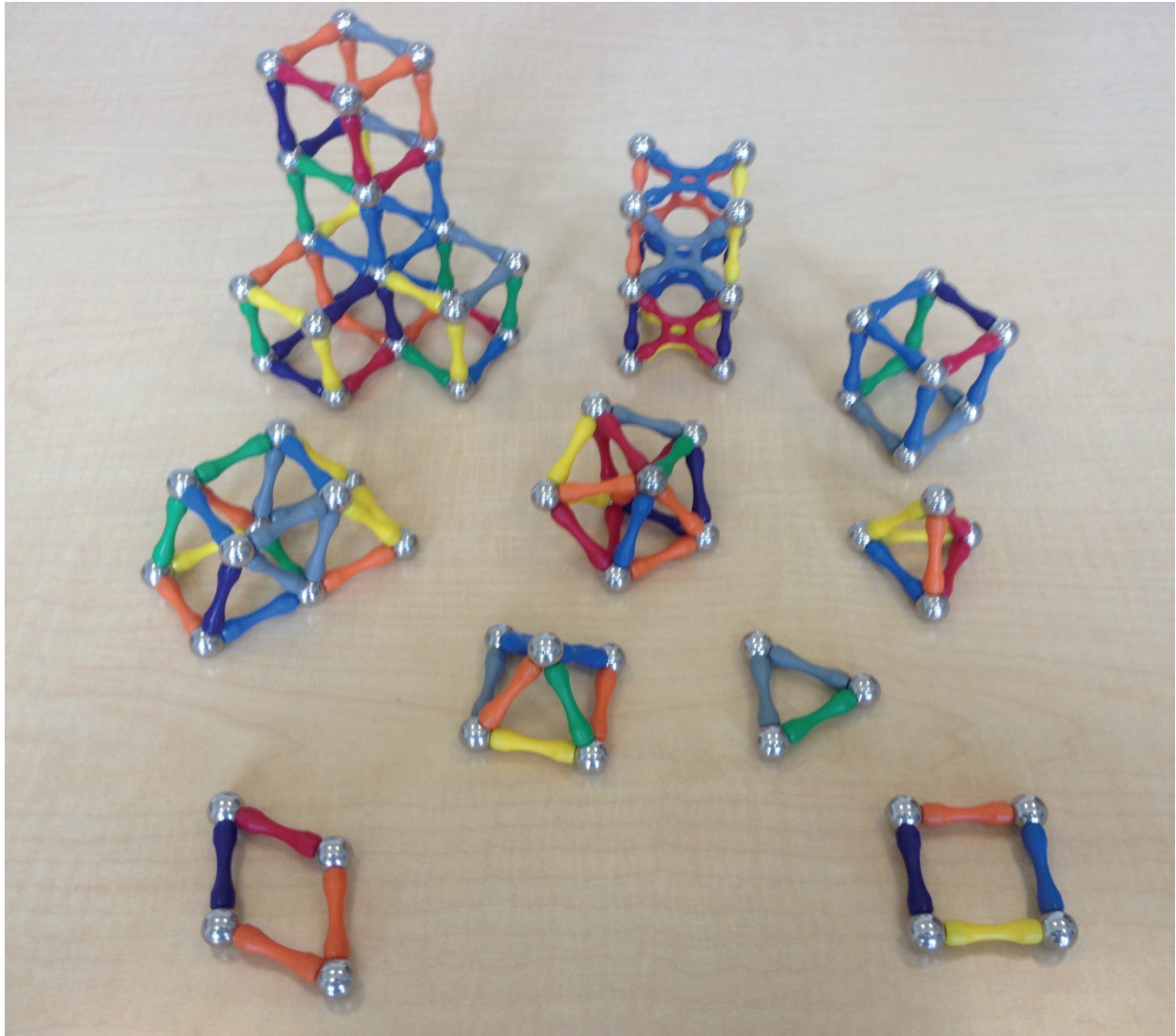
Figure 5. Modular Mighty Magz.



*Figure 6.* Modular Mighty Magz: 2" x 8" x 1" rectangle block, 2" x 6" x 1" rectangle block, 2" x 2" x 1" special direction square block, 2" x 2" x 1" square block, 2" x 4" x 1" rectangle block, 2" x 2" x 1" triangle block, 2" x 4" x 1" triangle block.



*Figure 7. Mega Magz.*



*Figure 8.* Mega Magz: 144 Steel balls, 24 four-point pieces, and 307 rods.





Figure 9. Mean score of correct answers to interview Part 1 (magnet and magnetic field questions).

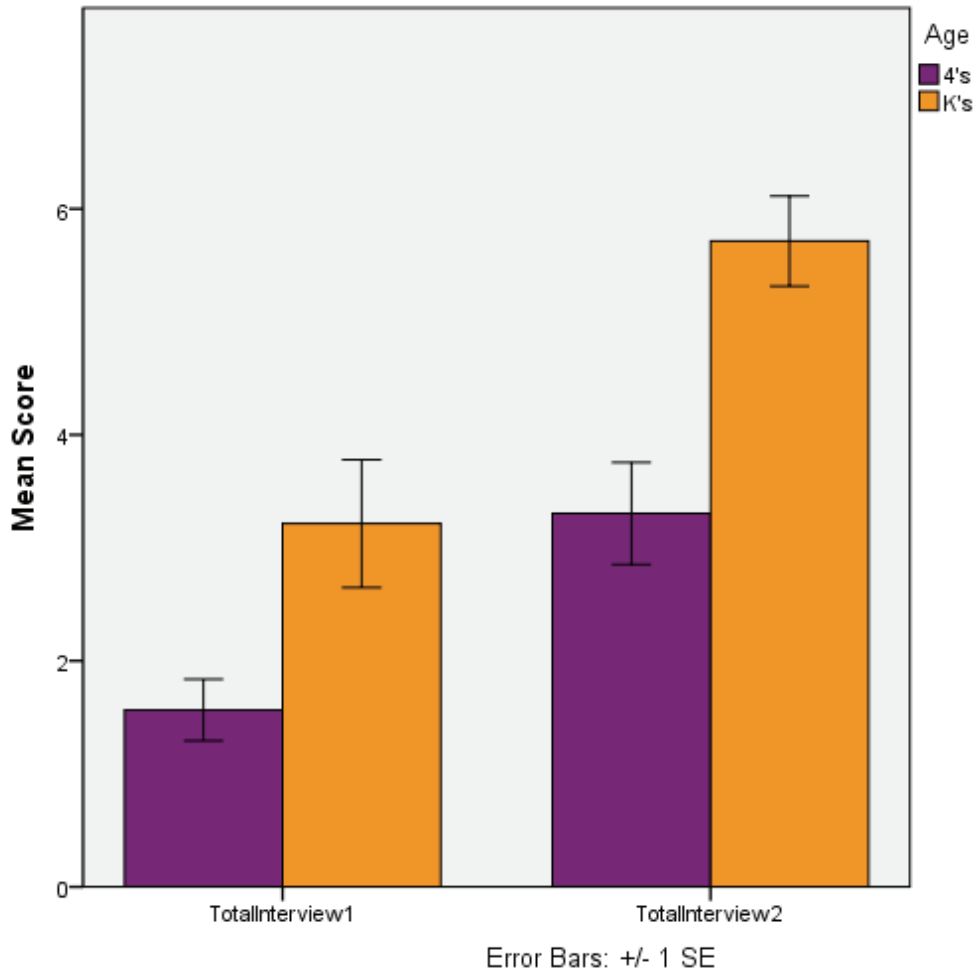


Figure 10. Mean score of correct answers to interview Part 3 (magnetic versus non-magnetic objects) for kindergarten children.

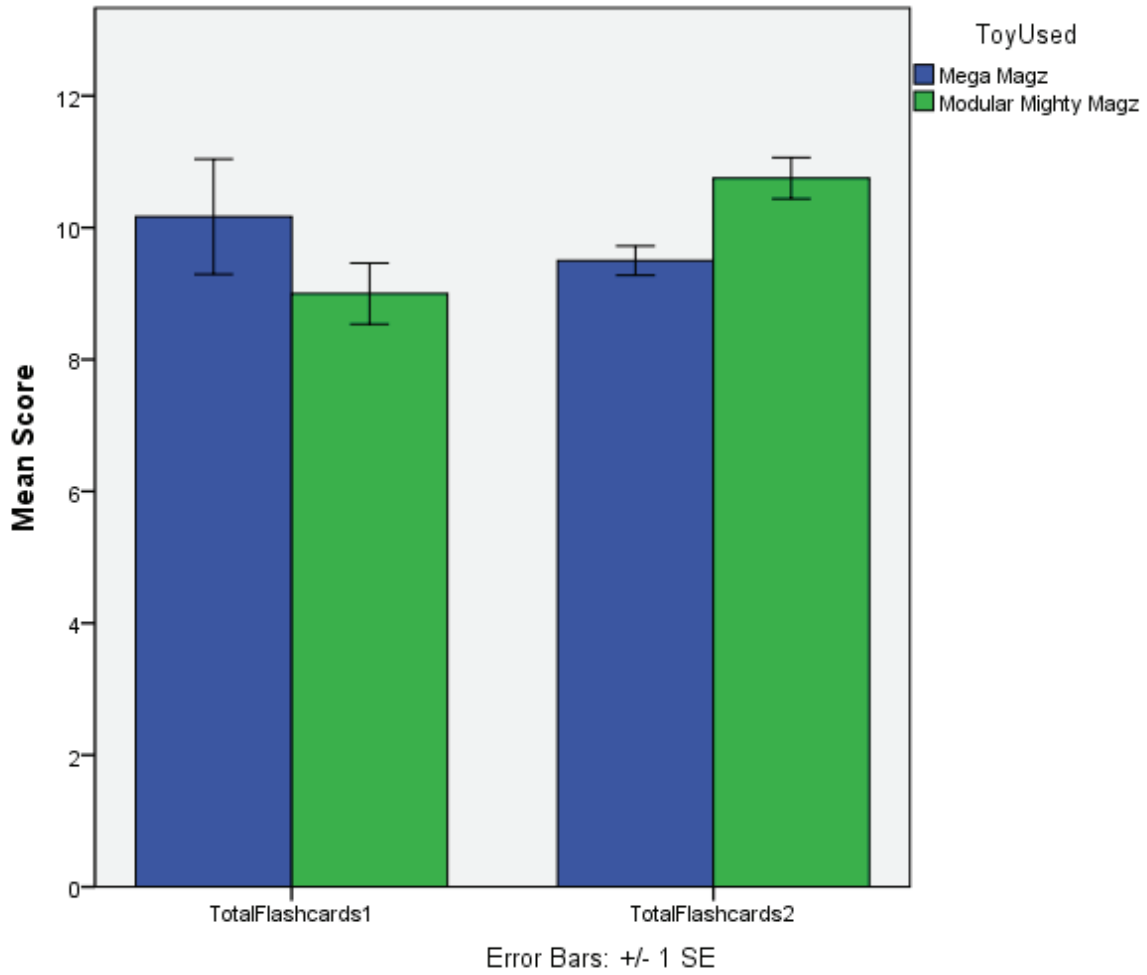


Figure 11. Overall mean time of collaboration in minutes for children playing with Mega Magz versus Modular Mighty Magz.

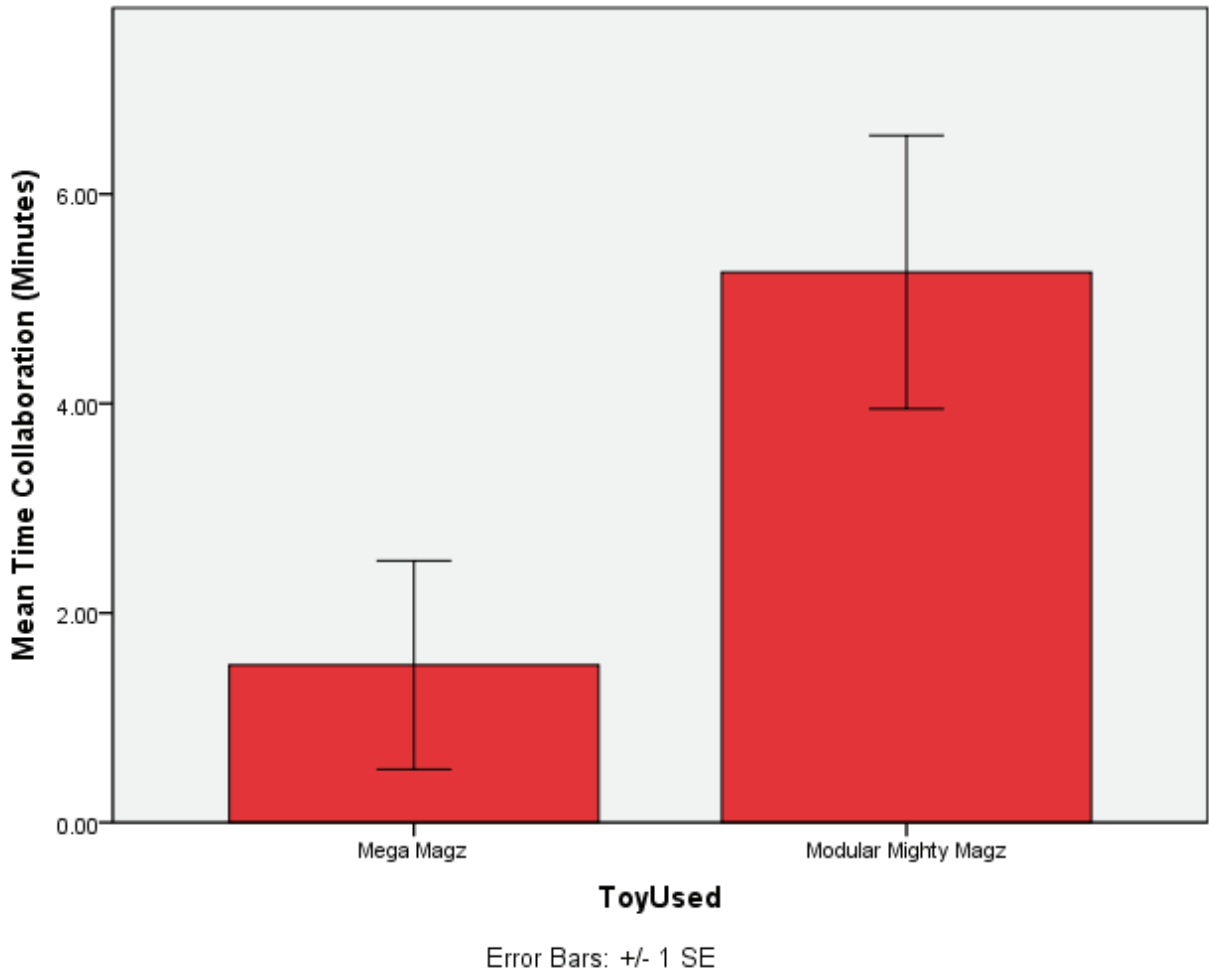
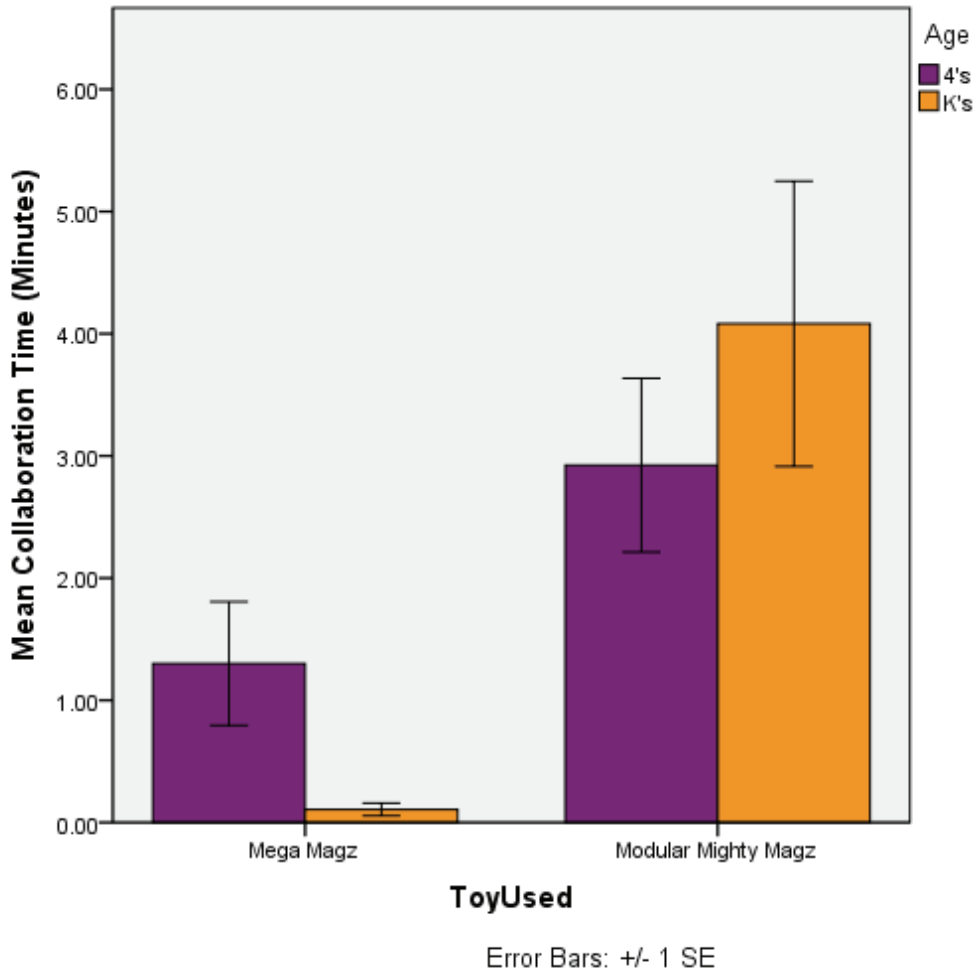


Figure 12. Mean time of collaboration in minutes for children playing with Mega Magz versus Modular Mighty Magz by age group.



*Figure 13.* Child just discovering repelling forces and magnetic field of Modular Mighty Magz.



*Figure 14.* Three children collaborating with Modular Mighty Magz while one child plays alone.



*Figure 15.* One child plays on floor while the other three children play on the table with Mega Magz.



Table 1

*Number of children in each test condition.*

<u>Number of Children In Each Condition</u>				
	Modular Mighty Magz		Mega Magz	Total
<u>Four-Year-Olds</u>	11		12	23 ( <i>M</i> = 4 years, 10 months)
	5 Males	6 Females	7 Males 5 Females	
<u>Kindergarten</u>	8		6	14 ( <i>M</i> = 5 years, 7 months)
	5 Males	3 Females	3 Males 3 Females	
<u>Total</u>	19		18	37 ( <i>M</i> = 5 years, 1 month)

\* Five children were excluded in addition to the above participants. Two kindergarten children and one four-year-old were excluded for not being available for the post-test. One kindergarten and one four-year-old were excluded for not being available for the teacher lesson and play day.



Table 2

*Differences and similarities of affordances for collaboration and learning magnetic concepts between Modular Mighty Magz and Mega Magz.*

<u>Differences and Similarities</u>		
	Modular Mighty Magz	Mega Magz
<u>Collaboration</u>		
Play Space	<ul style="list-style-type: none"> <li>- The play space is designed for four children where they are forced to either share the space or work collaboratively to fill up the area with structures.</li> <li>- There is no designation of an individual play space unless two or fewer children use the toy.</li> </ul>	<ul style="list-style-type: none"> <li>- <i>There is no play space designed for play with the toy. It is up to the teacher or parent to use an area or table that would promote collaboration.</i></li> <li>- A table that can hold four children was used to encourage collaboration. All the children could easily see one another's structures and move to work with them if they desired.</li> </ul>
Strength of Magnets	<ul style="list-style-type: none"> <li>- The magnets are more powerful than any common magnet toy on the market. Depending on the strength of the children, the larger blocks could require two children to pull them off the steel plate.</li> </ul>	<ul style="list-style-type: none"> <li>- <i>Magnets are very weak and one child can easily pull them apart. There is no need for two or more children to pull the pieces apart.</i></li> </ul>
<u>Magnetic Concepts</u>		
North and South Poles	<ul style="list-style-type: none"> <li>- This toy is purposefully marked abstractly with different color woods (cherry and walnut) to distinguish that the two opposite poles attract while similar poles repel.</li> </ul>	<ul style="list-style-type: none"> <li>- There is no indication of the north or south pole on each magnet.</li> <li>- Children only discover the poles by guessing or feeling for attraction or</li> </ul>

	<ul style="list-style-type: none"> <li>- Cherry is the north pole and walnut is the south pole.</li> </ul>	<p>repulsion of the magnetic pieces.</p>
Attracting	<ul style="list-style-type: none"> <li>- There is a very strong attraction between the magnetic blocks.</li> <li>- Children can feel the blocks coming together very easily.</li> <li>- Children can make the blocks jump together by slowly inching them together from a distance. This allows them to see the attraction.</li> <li>- The blocks can be hard to take apart to reinforce the idea of attraction.</li> </ul>	<ul style="list-style-type: none"> <li>- Magnets stick together reinforcing attraction.</li> <li>- They have a fairly weak attraction but they do stick together pretty well.</li> <li>- Magnets have to be fairly close before they jump together to see the attraction.</li> </ul>
Repelling	<ul style="list-style-type: none"> <li>- There is a very strong repulsion due to the strength of the magnets inside the blocks.</li> <li>- Children quickly realize by the strength of the magnets and blocks that similar poles do not go together. This is reinforced by the colors of the woods (cherry and walnut).</li> <li>- Children can see the repulsion by not being able to put similar poles (similar woods) together or pushing the blocks around the floor with the blocks repelling.</li> </ul>	<ul style="list-style-type: none"> <li>- There is a very weak repulsion in the magnets.</li> <li>- Repulsion can be found by placing the magnets on the ground and pushing them around or feeling it by putting two similar magnetic poles together with their hands, but this is not very obvious due to the weak magnets.</li> </ul>

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Sticking To Other Objects	<ul style="list-style-type: none"> <li>- Magnetic blocks will stick fairly strongly to other objects that are magnetic.</li> <li>- Child could easily pick up small objects that are magnetic.</li> <li>- There is an aluminum support bar on the play space that the child may discover is not magnetic, reinforcing magnetic versus non-magnetic objects.</li> <li>- <i>But children could get confused that wood is magnetic.</i></li> </ul>	<ul style="list-style-type: none"> <li>- Pieces will stick to objects that are magnetic.</li> <li>- Includes steel balls where children learn that magnets stick to metal. However a few children seem confused by the toy and think the metal balls are magnetic.</li> <li>- Pieces will not pick up objects that are magnetic unless they are very tiny like a staple, nail, or pin.</li> <li>- <i>But children could get confused that plastic is magnetic.</i></li> </ul>
Magnetic Fields	<ul style="list-style-type: none"> <li>- Since the blocks have very strong magnets, children can make the blocks repel and use a circular motion to feel the limits of the magnetic field.</li> </ul>	<ul style="list-style-type: none"> <li>- Since the magnet pieces are super weak, it is very hard to make the magnets repel and feel the magnetic field. It would be a very faint feel.</li> </ul>

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Table 3

*Means and standard deviations of results from the magnet and magnetic field questions. The maximum score was nine points and the minimum score was zero points on this part of the test.*

<u>Magnet and Magnetic Field Questions</u>		
	Pre-Test Interview	Post-Test Interview
<u>Four-Year-Olds</u> (N = 23)	$M = 1.57$	$M = 3.30^{**}$
	$SD = 1.31$	$SD = 2.16$
Modular Mighty Magz (N = 11)	$M = 1.36$	$M = 2.82$
	$SD = 1.21$	$SD = 2.52$
Mega Magz (N = 12)	$M = 1.75$	$M = 3.75$
	$SD = 1.42$	$SD = 1.77$
<u>Kindergarten</u> (N = 14)	$M = 3.21$	$M = 5.71^{**}$
	$SD = 2.12$	$SD = 1.49$
Modular Mighty Magz (N = 8)	$M = 3.50$	$M = 6.25$
	$SD = 2.51$	$SD = 1.49$
Mega Magz (N = 6)	$M = 2.83$	$M = 5.00$
	$SD = 1.60$	$SD = 1.27$

\*Statistically significant at 0.05

\*\*Statistically significant at 0.01

M.S. Marginally significant at 0.10

Table 4

*Means and standard deviations of results from the magnetic pole questions. The maximum score was three points and the minimum score was negative three points on this part of the test.*

<u>Magnetic Pole Questions</u>		
	Pre-Test Interview	Post-Test Interview
<u>Four-Year-Olds</u> (N = 23)	<i>M</i> = 0.52	<i>M</i> = 1.22*
	<i>SD</i> = 0.85	<i>SD</i> = 1.41
Modular Mighty Magz (N = 11)	<i>M</i> = 0.55	<i>M</i> = 1.09
	<i>SD</i> = 0.82	<i>SD</i> = 1.38
Mega Magz (N = 12)	<i>M</i> = 0.50	<i>M</i> = 1.33
	<i>SD</i> = 0.91	<i>SD</i> = 1.50
<u>Kindergarten</u> (N = 14)	<i>M</i> = 0.43	<i>M</i> = 2.29*
	<i>SD</i> = 2.24	<i>SD</i> = 1.20
Modular Mighty Magz (N = 8)	<i>M</i> = 0.37	<i>M</i> = 2.50
	<i>SD</i> = 2.39	<i>SD</i> = 0.76
Mega Magz (N = 6)	<i>M</i> = 0.50	<i>M</i> = 2.00
	<i>SD</i> = 2.26	<i>SD</i> = 1.67

\*Statistically significant at 0.05

\*\*Statistically significant at 0.01

M.S. Marginally significant at 0.10

Table 5

*Means and standard deviations of results from the magnetic versus non-magnetic object questions. The maximum score was twelve points and the minimum score was zero points on this part of the test.*

	<u>Magnetic Versus Non-Magnetic Object Questions</u>	
	Pre-Test Interview	Post-Test Interview
<u>Four-Year-Olds</u> (N = 23)	<i>M</i> = 8.48	<i>M</i> = 9.04
	<i>SD</i> = 2.17	<i>SD</i> = 2.38
Modular Mighty Magz (N = 11)	<i>M</i> = 8.64	<i>M</i> = 8.91
	<i>SD</i> = 2.38	<i>SD</i> = 3.02
Mega Magz (N = 12)	<i>M</i> = 8.33	<i>M</i> = 9.17
	<i>SD</i> = 2.06	<i>SD</i> = 1.75
<u>Kindergarten</u> (N = 14)	<i>M</i> = 9.50	<i>M</i> = 10.21**
	<i>SD</i> = 1.74	<i>SD</i> = 0.98
Modular Mighty Magz (N = 8)	<i>M</i> = 9.00	<i>M</i> = 10.75*
	<i>SD</i> = 1.31	<i>SD</i> = 0.89
Mega Magz (N = 6)	<i>M</i> = 10.17	<i>M</i> = 9.50
	<i>SD</i> = 2.14	<i>SD</i> = 0.55

\*Statistically significant at 0.05

\*\*Statistically significant at 0.01

M.S. Marginally significant at 0.10

Table 6

*Percentages of correct responses to the magnetic versus non-magnetic object questions.*

*Participants scores were averaged over all three sets since no difference was found ( $p > 0.05$ ).*

<u>Percentages of Correct Responses to Magnetic Versus Non-Magnetic Object Questions</u>				
	Four-Year-Olds	Four-Year-Olds	Kindergarten	Kindergarten
	Modular Mighty Magz	Mega Magz	Modular Mighty Magz	Mega Magz
	N = 11	N = 12	N = 8	N = 6
	Pre-Test / Post Test	Pre-Test / Post Test	Pre-Test / Post Test	Pre-Test / Post Test
<u>Magnetic Objects</u>				
Metal Desk Items	55% / 64%	67% / 92%	75% / 100%	100% / 67%
Metal Tools	64% / 91%	50% / 67%	75% / 100%	83% / 83%
Metal Hardware	82% / 64%	58% / 67%	63% / 100%	100% / 83%
Metal Silverware	82% / 82%	67% / 67%	88% / 88%	83% / 100%
Metal Sewing Items	45% / 55%	58% / 75%	75% / 75%	83% / 83%
Magnets	91% / 91%	83% / 100%	100% / 100%	100% / 100%
<u>Non-Magnetic Objects</u>				
Plastic	73% / 82%	92% / 83%	100% / 88%	100% / 100%
Wood	91% / 91%	92% / 92%	100% / 100%	100% / 83%
Aluminum	64% / 64%	83% / 83%	63% / 75%	50% / 67%
Copper	64% / 55%	42% / 67%	38% / 75%	67% / 50%
Gold	82% / 73%	58% / 42%	25% / 75%	50% / 33%
Rubber	73% / 82%	92% / 83%	100% / 100%	100% / 100%

Table 7

*Means and standard deviations of collaboration time with either Modular Mighty Magz or Mega Magz. The maximum amount of time to collaborate was fifteen minutes whereas the minimum amount of time to collaborate was zero minutes.*

	<u>Time (Minutes) Collaborating With Toy</u>	
	Modular Mighty Magz	Mega Magz
<u>Four-Year-Olds</u> (N = 23)	$M = 3.44^{**}$	$M = 1.20$
	$SD = 2.30$	$SD = 1.63$
<u>Kindergarten</u> (N = 14)	$M = 4.08^{**}$	$M = 0.11$
	$SD = 3.30$	$SD = 0.13$

\*Statistically significant at 0.05

\*\*Statistically significant at 0.01

M.S. Marginally significant at 0.10



## Appendix A

### Pre- and Post-Magnet Interview:

“Hi [child’s name]! My name is Ben. I would like to ask you some questions about magnets before we play a game involving them. Do you understand? (Explain again if the child says no or provides no response.)

(Repeat any question again if there is no response or child does not understand. If still no response or idea of what question is asking, use provocations in order until receive a response. Mark if provocations used and how many.)

### Part 1A

“Tell me what you know about magnets.” (2 points)

Provocation 1: “What can we do with magnets?”

Provocation 2: “Where do you use or have you seen magnets at school?”

Write Response:

1 point for something about sticking together or another object.

1 point for attracting metal.

“Tell me what a north and south pole on a magnet is.” (3 points)

Provocation 1: “What do you think the north and south pole on a magnet might do?”

Provocation 2: “Think about if you have played with a magnet that has an N and S on it. What have you noticed happens near those letters?”

Write Response:

1 point for things stick to them.

1 point for north and north poles or south and south poles not going together.

1 point for north and south poles going together.

“Tell me what the word ‘attract’ means.” (1 point)

Provocation 1: “Stick is a similar word to attract. Tell me what ‘stick’ means.”

Write Response:

1 point for different word correctly explaining idea than word used in provocation.

“Tell me what the word ‘repel’ means.” (1 point)

Provocation 1: “Push back is similar to the word repel. Tell me what ‘push back’ means.”

Write Response:

1 point for different word correctly explaining idea than word used in provocation.

### Part 2

“Will a north and a north pole attract or repel each other?” (1 point)

Response:  Attract  Repel  Do Not Know

1 point for correct answer, 0 points for Do Not Know, -1 point for incorrect answer.

“Will a south and a south pole attract or repel each other?” (1 point)

Response:  Attract  Repel  Do Not Know

1 point for correct answer, 0 points for Do Not Know, -1 point for incorrect answer.

“Will a north and a south pole attract or repel each other?” (1 point)

Response:  Attract  Repel  Do Not Know

1 point for correct answer, 0 points for Do Not Know, -1 point for incorrect answer.

**Part 3**

“Alright we are going to play with magnets now. See this magnet? I will show you some pictures and tell you the names of the objects. I want you tell me if it would attract the material in the flash card in real life and why. Do you understand?” [Tell the child the names of the materials along this process over and over again until finished presenting all the flash cards. Record responses after each flash card is presented.] (See response sheets at end of protocol.)

Set 1 (12 Points)	Set 2 (12 Points)	Set 3 (12 Points)
Magnetic Objects: Metal Paperclip Metal Wrench Metal Screw Metal Spoon Metal Thimble Bar Magnet	Magnetic Objects: Metal Key Ring Metal Hammer Metal Nut Metal Knife Metal Needle Horseshoe Magnet	Magnetic Objects: Metal Thumbtack Metal Screwdriver Metal Nail Metal Fork Metal Safety Pin Circular Magnet
Nonmagnetic Objects: Plastic Container Wood Blocks Aluminum Foil Copper Penny Gold Coin Rubber Band	Nonmagnetic Objects: Plastic Bottle Wood Toy Car Aluminum Soda Can Copper Wire Gold Ring Rubber Boots	Nonmagnetic Objects: Plastic Silverware Wood Toy Train Aluminum Tray Copper Rod Gold Necklace Rubber Ball

**Part 1B**

“Alright we are going to do one more task. First tell me what a ‘magnetic field’ means.”

Provocation 1: “Think about what happens to objects and other magnets really close near magnets.” (1 point)

Write Response:

1 point for talking about area, region, or space around a magnet.

“I am going to give you two magnets. Show me where the magnetic field is.” (When finished take the magnets back) (1 point)

Write Response:

1 point for demonstrating attracting or repelling and talking about area in-between the two magnets.

“Alright you are done now. Great job! Let me give you a sticker and we will head back to the classroom.” (Return child back to the classroom.)

**Part 3 Sample Response Sheet**

**Response Card for Flash Cards:** Randomly shuffle the cards each time. Circle whether the child says yes or no to magnetic and then record response for why.

Set 1: Magnetic (Yes/No) (12 points)

Metal Paperclip      Y/N      1 point for correct answer.

Metal Wrench      Y/N      1 point for correct answer.

Metal Screw      Y/N      1 point for correct answer.

Metal Spoon      Y/N      1 point for correct answer.

Metal Thimble      Y/N      1 point for correct answer.

Bar Magnet      Y/N      1 point for correct answer.

Plastic Container      Y/N      1 point for correct answer.

Wood Blocks      Y/N      1 point for correct answer.

Aluminum Foil      Y/N      1 point for correct answer.

Copper Penny      Y/N      1 point for correct answer.

Gold Coin      Y/N      1 point for correct answer.

Rubber Band      Y/N      1 point for correct answer.

Appendix B

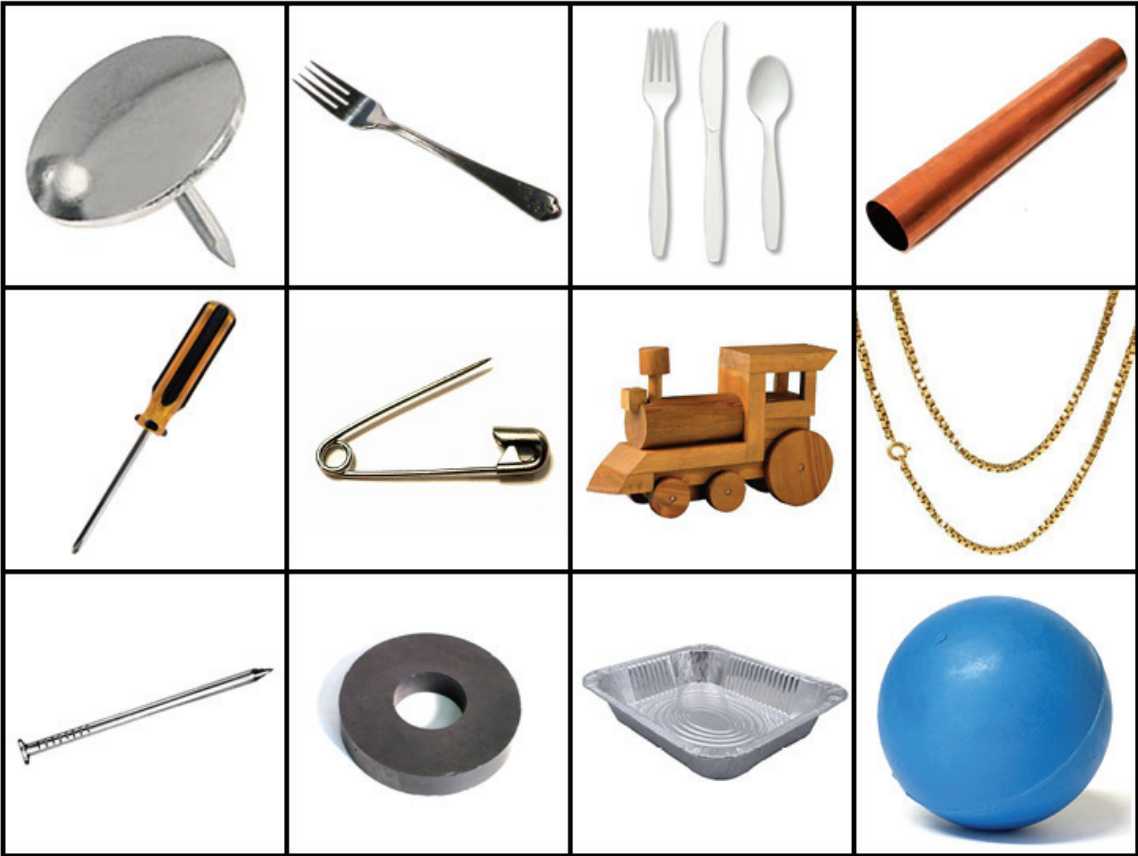
Flash Cards Set 1



Flash Cards Set 2



Flash Cards Set 3



### Appendix C

**Concepts to learn:** North and South Poles, Attract, Repel, Magnetic Fields, and What Makes Something Magnetic.

**Duration:** 15-20 minutes

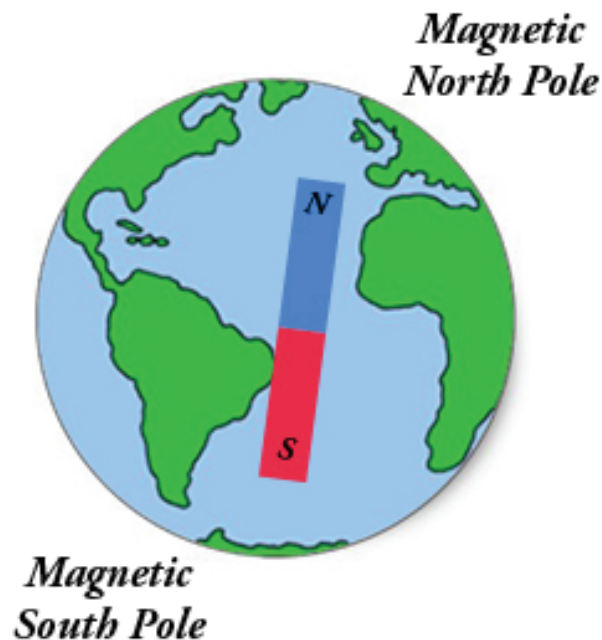
**Teacher Script: (Try to stay as close to this as possible.)**

“Good morning friends! Today during circle time we are going to learn about magnets and their properties. First raise your hand if you can tell me something about magnets?” (Try to gauge what the children do and do not know about magnets aligned with the concepts I am trying to teach. Take a few responses and then move on.) **Record responses on a large sheet of paper for the children to see and write their initials next to it.** (Save for future analysis.)

“The first magnet concept we will learn about is **north** and **south** poles. Can anyone raise their hand and tell me about the north and south poles of a magnet?” (Take a few responses and then move on.) **Record responses on a large sheet of paper for the children to see and write their initials next to it.** (Save for future analysis.)

[If children mention the earth as a magnet, explain how it works. (“The earth is a giant magnet with a north pole near the real north pole and a south pole near the real south pole. But in reality they are not at the exact north and south pole location.” Draw a picture explaining it or use the image below.)]

[If they ask can you see the magnet, say “No, but it is there. It is like gravity or wind. We know they exist and can demonstrate it, but we cannot see them.”]



“Alright I am going to show you where the poles are located on a magnet.” (Draw a rectangle similar to the magnet provided for instruction. Then draw an N and S to represent the north and south pole axial through the magnet. Explain the process of the poles location while drawing.) See example below.

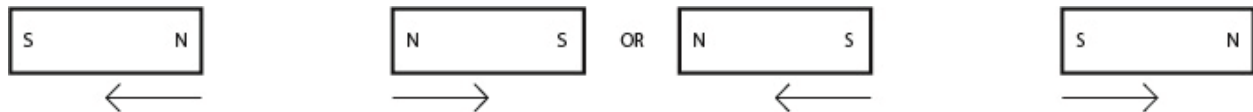


“Now the way magnets stick together is based on the idea of **attracting** and **repelling**. When magnets **attract**, it means that two opposite poles will stick together. This means that a north and a south pole will stick together.” (Draw a picture showing how the two magnets go together.) See example below.



(Then demonstrate with the magnets provided for the children how this concept works.)

“**Repelling** means that the magnets will not stick together. This means that a north and a north or a south and a south pole will not stick together.” (Draw a picture showing how the two poles would look not going together.) See example below.



(Then demonstrate with the magnets provided for the children to see how this works.)

“Alright I am going to give each of you a pair of magnets to try these concepts. I want you to think about the pictures I have drawn when playing with the magnets. Try to feel the magnets pulling each other together, which is attracting, or pushing each other apart, which is repelling.” (Then give the children the magnets and have them try it for themselves.)

[If the children get confused that the magnets are not the same, say that “Magnets can come in all different shapes and sizes.” The circular magnets are marked with an N and S so that you can point out to the children and show its similarities to the bar magnet used for demonstration.]

“Friends let’s learn about another magnetic concept I want you to try to see. Magnets have something called a **magnetic field**. This magnetic field is the area that a magnet repels or attracts a magnet that is close by. The stronger the magnet, the bigger the field is. Also the stronger the magnet is, the harder they are to pull apart. To feel the magnetic fields, make the magnet repel and move them in a circular motion. Watch me first and then try it for yourselves. (Demonstrate for the children.) Notice how you feel different forces or strengths of repelling.



This is where the magnet field is. The stronger the magnet is, the bigger this magnetic field will be. Also the closer you move the magnets together, the stronger the magnetic field is. You can feel the different strengths of the magnetic field by slowly moving the magnets close together. Slowly inch them closer and watch them stick or repel one another. Watch me first and then try it for yourselves.” (Demonstrate for the children. Place a magnet on the ground and slowly move it close till it jumps up and attracts or slowly move it toward the magnet where it repels and point out how you feel a force and that they will not stick together.)

[If the children notice that the circular magnets stick to the side you can tell them “Yes, but it is a weak attraction at that point because of the magnetic field. The magnetic field is strongest at the poles and weakest at the sides.”]

“Ok friends one last concept to learn about. Who can tell me what kinds of things would stick to magnets?” (Take a few responses and move on.) **Record responses on a large sheet of paper for the children to see and write their initials next to it.** (Save for future analysis.)

“Friends magnets are made of certain metals that allow them to attract and repel one another. This means that they are able to pick up other objects if they contain similar metals in them by temporarily turning them into weak magnets. Let’s see what materials we can and cannot pick up with the magnets.” (There will be two bowls provided with objects that are magnetic in one bowl and others that are not in the other bowl. Place a few objects (3-4) on the tray at a time where they can all see it and ask the children, “Which object will the magnet pick up?” Then use a magnet and see what happens for the children. Depending on time have each child make a choice or have them individually come up and do the activity with different objects.)

After the demonstration ask the children “What similarities made the objects magnetic or not?” (Take a few responses and move on.) **Record responses on a large sheet of paper for the children to see and write their initials next to it.** (Save for future analysis.)

[If you get a question about other things that are metal that are not magnetic, give some other examples of nonmagnetic metal materials. Examples can be gold, copper, brass, and aluminum. There will be aluminum foil in the basket which may confuse the children.]

“Alright friends it is time to clean up and stop. Please give me the magnets back.” (Proceed with the rest of circle time.)

## Appendix D

**Observational Methodology:** After the teacher's lesson is done during circle time, four children at a time will be brought to the green annex room to play with Modular Mighty Magz or Mega Magz on a table. They will be videotaped and allowed 15 minutes to play together. The children will be encouraged to keep playing and the observer will sit back and watch staying non-involved in the play unless provocation is needed. Use the following provocations provided to try and engage children to the next level of play.

**Levels of Block Play:** carrying, placing, building rows horizontally and vertically on a flat surface, stacking, bridging, enclosing, pattern making, naming structures, and then symbolizing.

**At 4 Minutes:** If children are still building flat, just placing objects, or building in vertical and horizontal rows, show how to stack and build up with the toys. For the Magnet Learning Center show how to stack blocks on one another out horizontally and vertically. For Mega Magz encourage and ask the children what happens if you tried to build vertically with the magnets.

Modular Mighty Magz: "What happens if you try to place a block on top of another one?" If they do not respond, demonstrate placing a block on top of another one.

Mega Magz: "What happens if you try to build vertically?" If they do not respond, demonstrate placing a magnet vertically.

**At 8 Minutes:** If children are just placing objects on top of other blocks randomly then demonstrate how to bridge and enclose spaces with the Magnet Learning Center. For example, show how blocks can work with both the metal and bottom board to hold up structures and make bridges and enclosed spaces. For Mega Magz show how to make 3D structures such as a cube.

Modular Mighty Magz: "What happens if you try to make a structure using both the bottom board and the metal?" Show how to make this type of bridging and space making.

Mega Magz: "What happens if you try to build other shapes such as 3D rectangles?" Try to make two cubes and then remove the support in between to make a 3D rectangle.

**At 12 Minutes:** If children have progressed to the highest level of block play by now, encourage and ask the children what kinds of patterns they can make with the blocks. Ask them what structures they are building. See if they are symbolizing the toys for other objects by asking questions such as "what are you making?"

Modular Mighty Magz: "What are you making [child's name]?" "What kinds of patterns can you make with the two colors of wood and different shapes?" Demonstrate making some patterns for the children such as two triangles together make a square or rectangle and place a few together alternating colors to make a pattern.

Mega Magz: "What are you making [child's name]?" "What kinds of patterns can you make with the different color rods?" Demonstrate making a cube with half one color and the other half another color to show making a triangle within a cube.

## Appendix E

### Parent Description: The Magnet Game

Your child participated in an experiment for Benjamin Howe's dual thesis. I am trying to design an educational toy for my BXA Capstone Project that demonstrates the fusion of my studies here at Carnegie Mellon University of Architecture and Psychology. I am using my design skills to make the toy and I am applying my psychology knowledge to see whether the toy is educational or not and fulfills requirements for my other thesis, the H&SS Honors Thesis. I am interested in demonstrating that my toy, which I am calling right now "The Magnet Learning Center," is engaging as well as effective in being educational and teaching children concepts about magnets. I would also like to demonstrate that my toy is more effective in teaching concepts about magnets than other toys on the market, such as Mega Magz. Every child was given a pre- and post-test interview that asked simple questions about concepts of magnets. The children were then given a lesson by the teachers on magnets and either randomly assigned to participate in a control group, where they played with a current market toy (Mega Magz), or an experimental group, where they played with my Magnet Learning Center, between the pre- and post-test interview. This research could be beneficial in providing a new educational magnet toy on the market for use in schools or informal settings at museums only if it can be demonstrated that the Magnet Learning Center truly has an educational impact that other magnet toys on the market may not be able to do as well.

(One of these three statements appeared depending on which part of the test the child had completed.)

**Today your child started the research process by participating only in the pre-test interview.**

**Today your child continued the research process by participating in the teacher lesson and playing with one of the two toys.**

**Today your child finished the research process by participating only in the post-test interview.**

Experimenter: Benjamin Howe

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